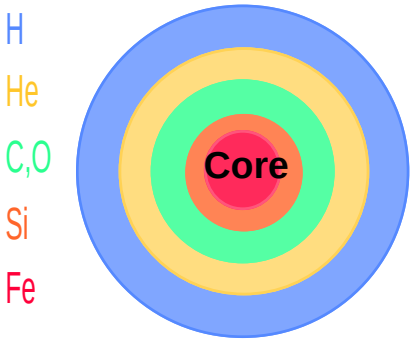
Hydrodynamics / Supernova explosions

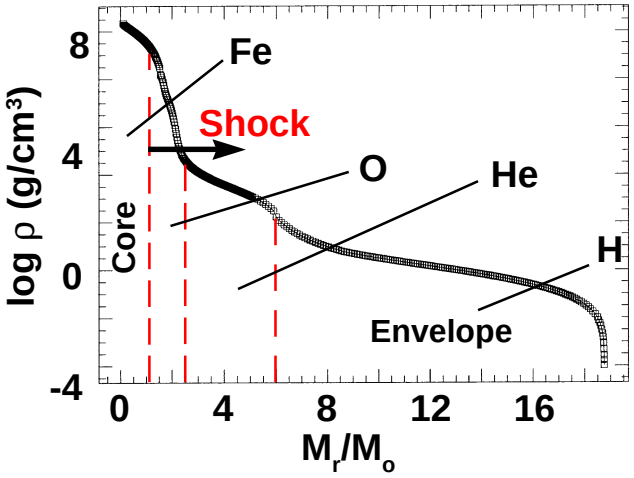
A core-collapse supernova occurs when the Fe core of a massive star collapses

"Onion skin" model

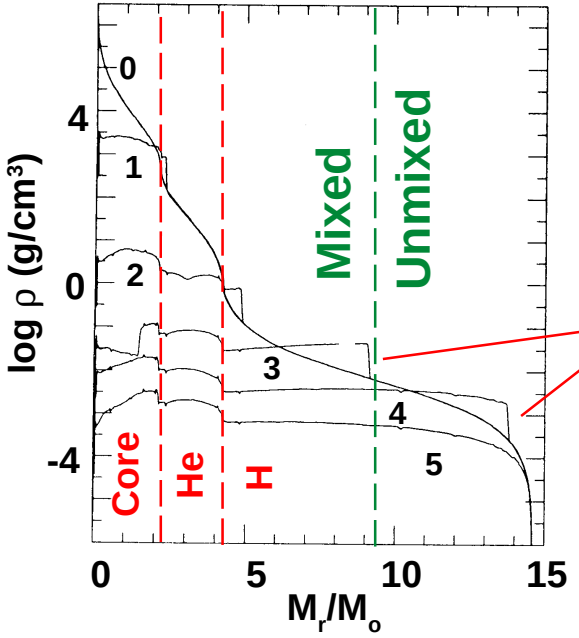


Arnett SN text (1996)

SN1987A progenitor



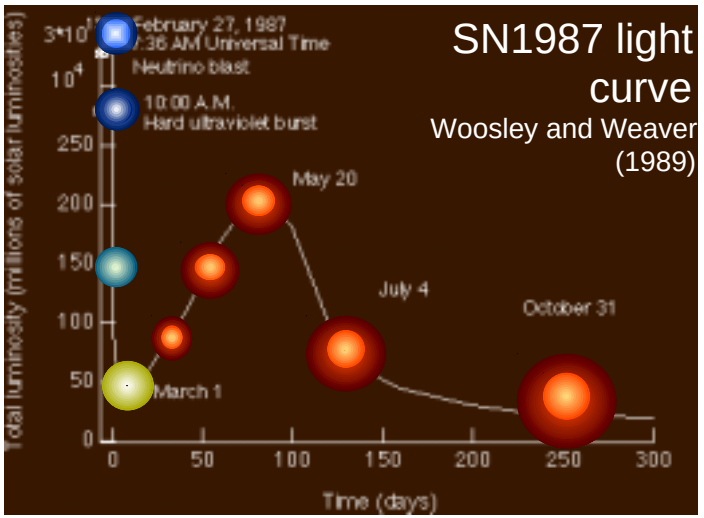
This launches a powerful shock



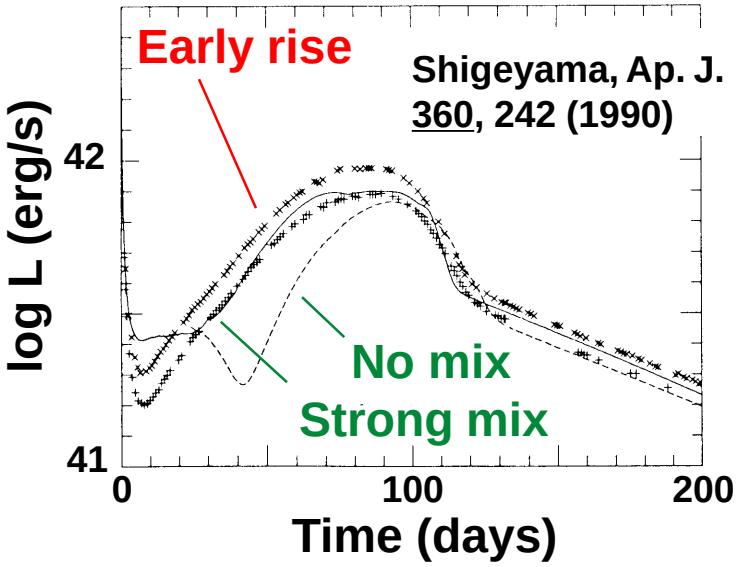
Curve	Time (sec)
0	0
1	9
2	167
3	1060
4	3330
5	7460

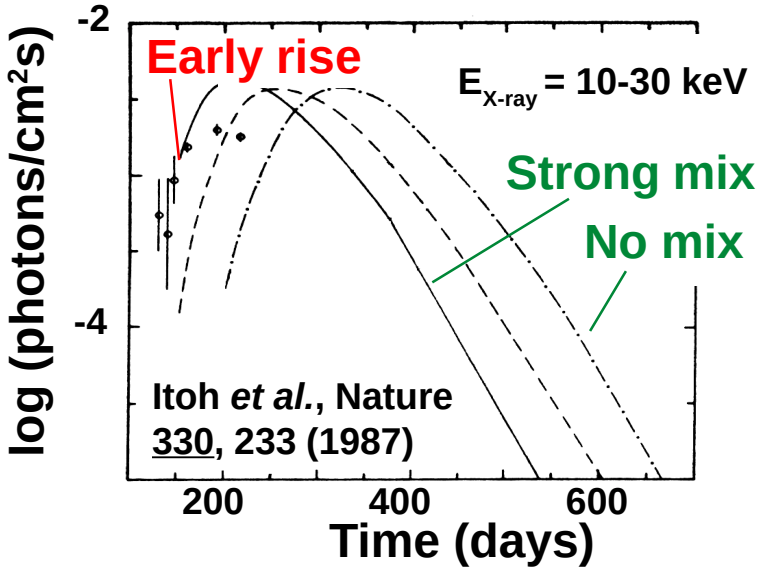
Shigeyama & Nomoto, Ap.J. 360, 242 (1990)

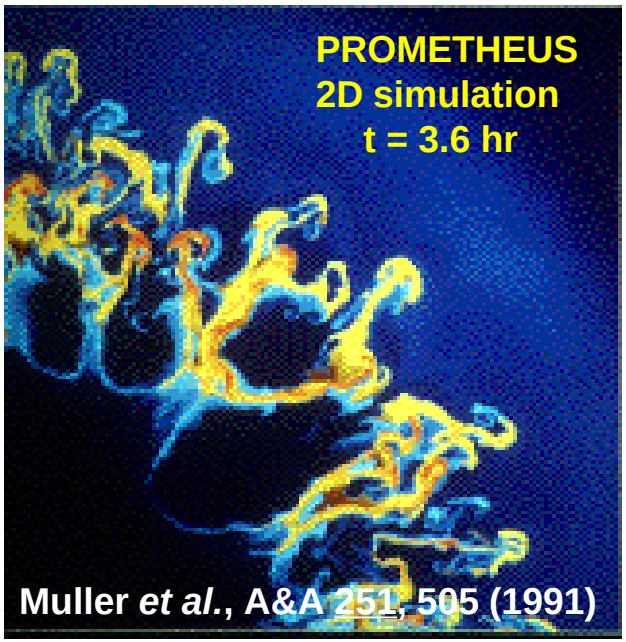
At shock breakout, we see the SN

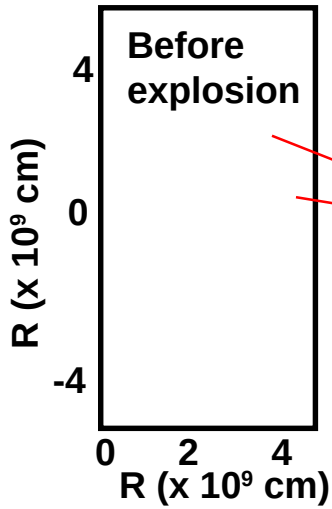


Observations from SN1987A suggest strong mixing of the radioactive core into the envelope









Convection cells in oxygen layer

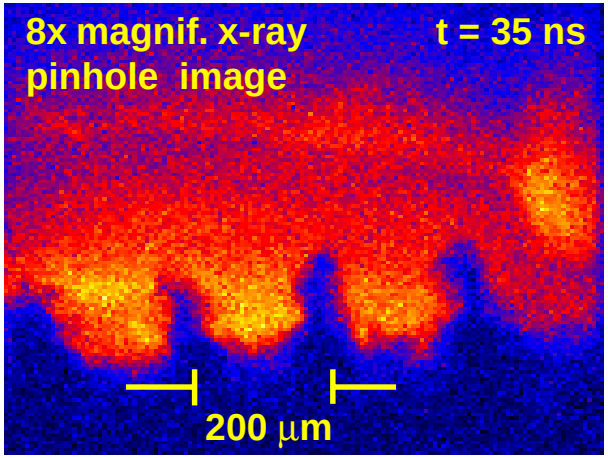
$\delta\rho/\rho$ ~ 10%

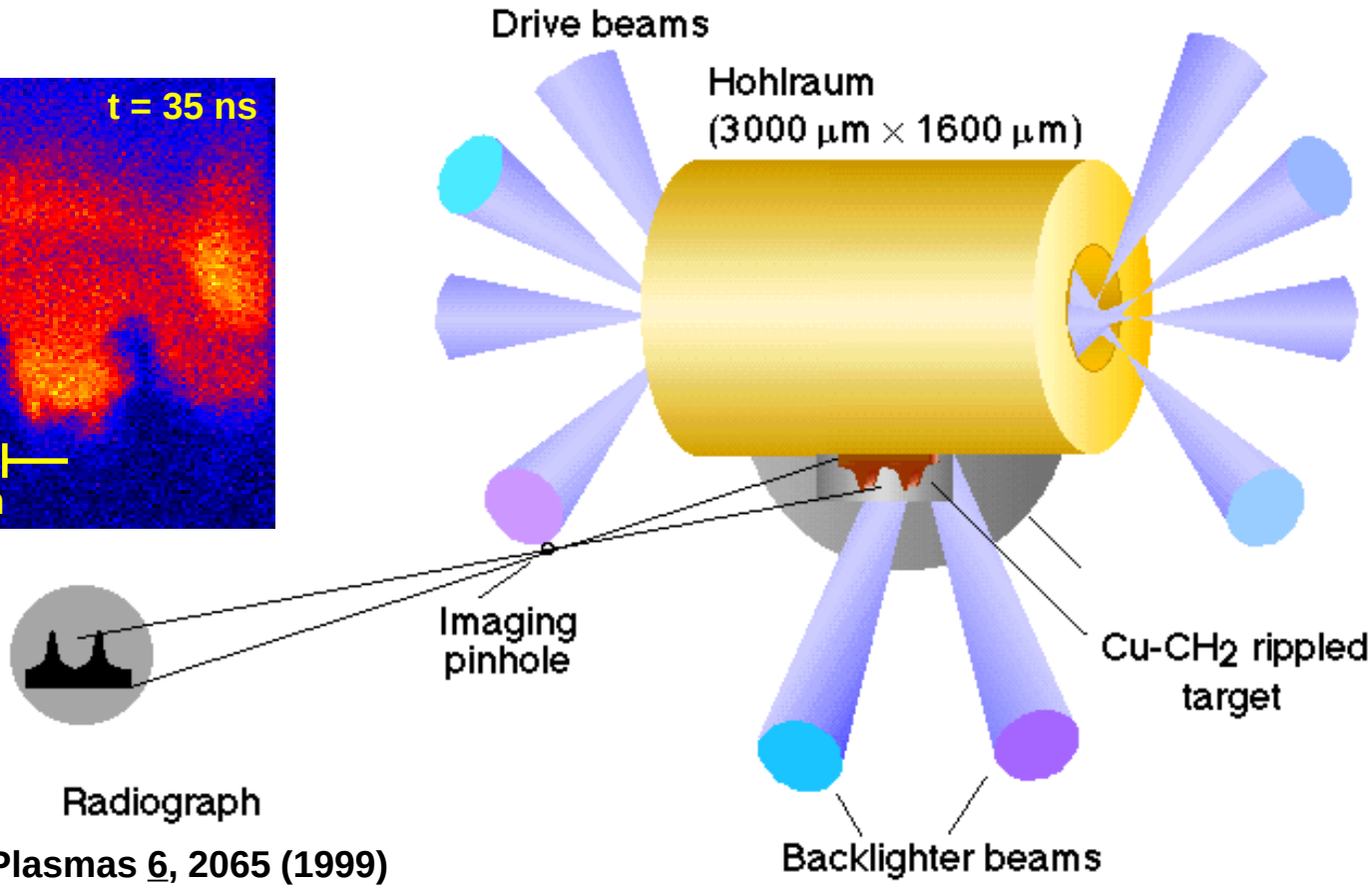
Bazan & Arnett, Ap. J. 496, 316 (1998)

- Core vel's still underpredicted
- "Input" or "output" problem?
- Experiments can answer this

Issues_SN_1d1.vg

Experiments relevant to the hydrodynamics of core-collapse SNe have been done on the Nova laser





Kane *et al.*, Phys. Plasmas 6, 2065 (1999)

- Sets of gated x-ray pinhole cameras are the diagnostics
- Separate laser beams generate hard x-rays for backlighting

Supernova explosion hydrodynamics at intermediate times obeys a scale transformation

- **The dynamics are described by Euler's Eqs. ("pure hydro"); viscous dissipation, heat transport can be neglected (Re >> 10^4, Pe >> 1)**

Conservation of mass: $$\frac{\partial \rho}{\partial t} + \nabla \bullet (\rho v) = 0$$

Conservation of momentum: $$\frac{\partial v}{\partial t} + (v \bullet \nabla) v = -\frac{\nabla p}{\rho}$$

Conservation of entropy: $$\frac{\partial p}{\partial t} - \gamma_a \frac{p}{\rho}\frac{\partial \rho}{\partial t} + v \bullet \nabla p - \gamma_a \frac{p}{\rho} v \bullet \nabla \rho = 0$$

- **Euler's Eqs. are invariant under this scale transformation:**

$\rho \longrightarrow a_1 \rho$

$p \longrightarrow a_2 p$

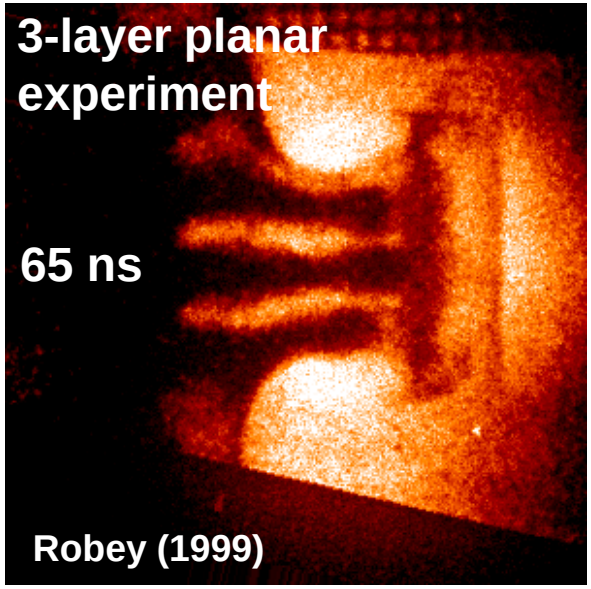
$h \longrightarrow a_3 h$

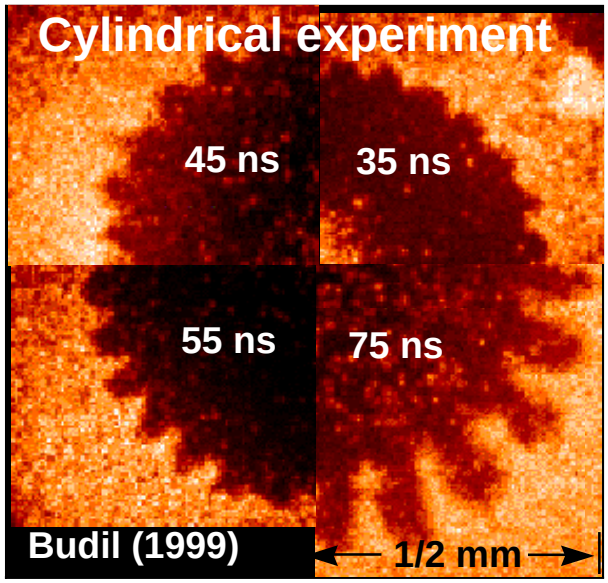
$\tau \longrightarrow a_3 (a_1/a_2)^{1/2} \tau$

SN		laser
$p/\rho_a = 10 g_0$	$\longrightarrow$	$10^{10} g_0$
$h = 10^{12}$ cm	$\longrightarrow$	100 μm
$\tau = 10^3$ sec	$\longrightarrow$	10 nsec

D. Ryutov *et al*., Ap. J. 518, 821 (1999)

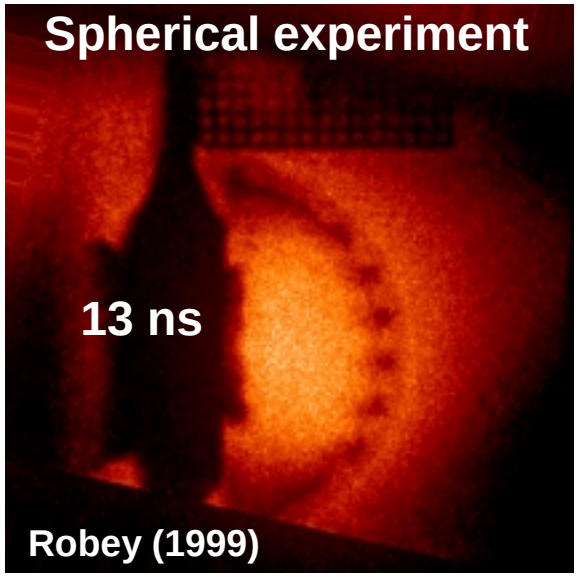
Supernova experiments that are more "star-like" are being developed on the Omega laser





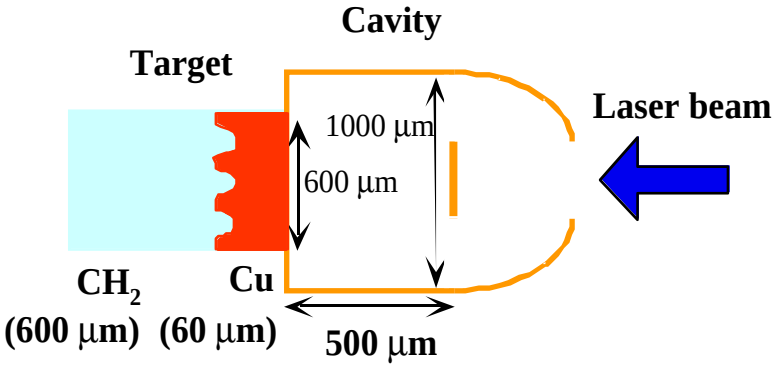
More "star-like":

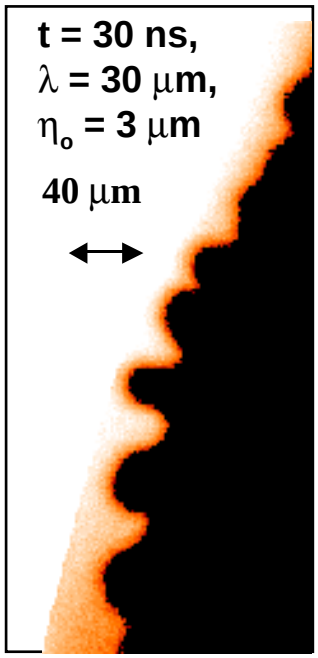
- 3-layers
- Divergent geometry
  - cylindrical
  - spherical

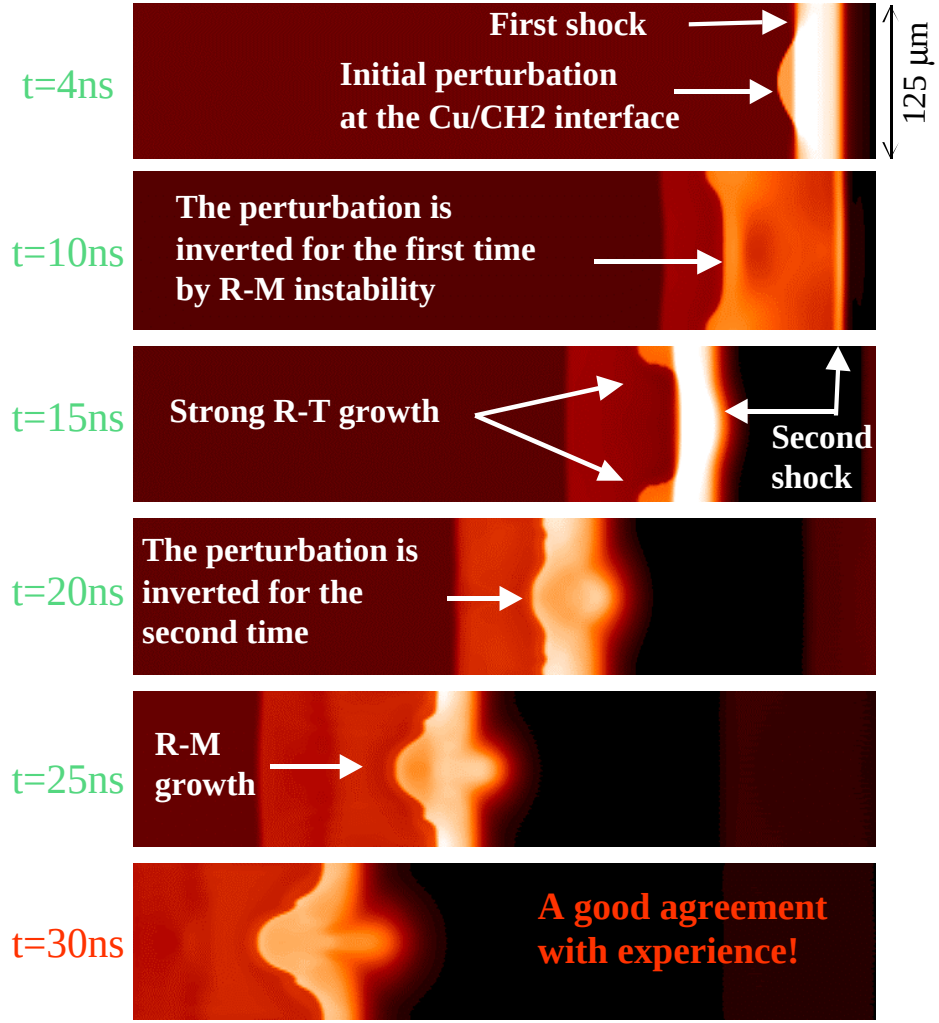


See Robey (RP1.95), Hurricane (RP1.95), Kane (RP1.94)

Experiments relevant to the mixing in SN explosions were conducted on the Phebus laser







Baclet, Teyssier *et al.*, IFSA conf. (1999)

Teyssier_1.vg